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DESERT POWER

Salton Sea Unit 3
Fact Sheet

Location: Imperial County, California; eight miles west of Calipatria at the southern tip of the Salton Sea.

Leases: Unocal holds geothermal leases on approximately 36,000 acres of potentially productive land in the Salton Sea area.

Cost: $110,000,000 (engineering and construction).

Resource Production

Number of wells	5 (2 producers and 3 injectors)
Deepest well drilled	Sinclair 23 at 7400 ft.
Production rates	2,500,000 lbs/hr for Vonderahe 1 1,750,000 lbs/hr for Sinclair 10
Average temp. of reservoir fluids	520° F
Total dissolved solids in reservoir fluids	200,000 to 300,000 parts per million
Steam production system	Flashed steam, 3 stages of separation to turbine
Steam requirement for power plant	617,000 lbs/hr at 100 psig 262,000 lbs/hr at 10 psig

Power Generation

Turbine	MHI 5-stage dual flow/ dual entry condensing type
Condenser	Ecolaire dual zone shell-and-tube
Noncondensible gas removal system	Nash-Kinema 3-stage ejector
Cooling tower	Marley 7 cell counterflow
Power sold to SCE	47,500 kw
Equivalent annual savings in oil	500,000 bbls
Construction commenced	December 1986
Commercial operation	February 14, 1989
Quantity of concrete	20,700 cu yds
Quantity of structural steel	835 tons
Total length of pipe	63,000 feet
Electrical wire and cable used	75 miles

April 1989

DISCLAIMER

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BACKGROUNDER

GEOTHERMAL RESOURCE PRODUCTION, STEAM GATHERING, AND POWER GENERATION AT SALTON SEA UNIT 3 CALIPATRIA, CALIFORNIA

April 1989

INTRODUCTION

The 10,000-kilowatt Salton Sea Unit 1 power plant was designed to demonstrate that electrical power generation, using the highly saline brines from the Salton Sea geothermal reservoir, was technically and economically feasible. Unit 1, owned by Earth Energy, a Unocal subsidiary, began operating in 1982, initiating an intensive testing program which established the design criteria necessary to construct the larger 47,500-kilowatt Unit 3 power plant. Unit 3 contains many of the proprietary or patented technological innovations developed during this program.

Design, construction and start-up of the Unit 3 power generating facility began in December, 1986, and was completed in 26 months. By the end of 1988, the brine handling system was in full operation, and the turbine had been tested at design speed. Desert Power Company, a Unocal subsidiary, owns the power generating facility. Unocal owns the brine resource production facility. Power is transmitted by the Imperial Irrigation District to Southern California Edison Company.

HISTORY OF THE SALTON SEA GEOTHERMAL AREA

In the mid 1850's W.P. Blake set out to explore a route for a railroad line from the Mississippi River to the Pacific Ocean. When he reached the part of the desert that is now the Salton Sea, he found spectacular thermal springs and geysers, which he documented in an account of his travels. Fifty years later, the 1905 Colorado River flood formed the Salton Sea and quenched most of the geothermal surface manifestations except for a few passive, gas-rich hot springs and several cool mud pots.

These thermal springs first attracted commercial interest in 1927. The Pioneer Development Company drilled three shallow wells to explore for steam. However, the heat provided from the wells was insufficient to support power generation. During the next ten years, more than fifty shallow wells were drilled to produce carbon dioxide for two dry ice plants. Concurrently, a well being drilled for potable water hit a very hot artesian source that gushed forth and created mud pots. Although the well was regarded as a failure and was abandoned, an entrepreneur named Theodore Pilger, who had experience with health spas, capitalized on the area by developing a popular hot mud bath resort for health-minded tourists. Pilger became the first of a series of commercial developers to tap the Salton Sea geothermal brines.

The first deep well to explore for oil was drilled into the Salton Sea anomaly by the Kent Imperial Corporation in 1958. Hot brine and steam were encountered instead. Although the well failed as a successful geothermal producer, it renewed interest in the exploration for geothermal steam.

Hot brine geothermal wells were drilled by P.H. O'Neill of Texas, Union Oil, Shell Oil, and Natomas. Other companies playing a major role in exploration and experimentation included Imperial Thermal Products, Geothermal Energy and Mineral, Magma Power, and Phillips Petroleum. Testing was aimed primarily at chemical extraction and mineral and salt recovery, with electrical power generation as a secondary product.

The need to develop geothermal energy became acute when our nation experienced the energy crises of the 1970's. The hot Salton Sea brines were recognized as potentially valuable for electrical power generation to help offset the need for imported fuel. Ten additional years of research and technological development were necessary to achieve commercial generation.

THE SALTON SEA GEOTHERMAL RESERVOIR

The Salton Sea geothermal reservoir is the largest of several hot brine geothermal resources within the Salton Trough in the Imperial Valley, California. The portion of the reservoir associated with the Unit 3 plant is located at the southern end of the Salton Sea geothermal anomaly (Figure 1, page 11).

The reservoir is composed of sand, silts and clays, deposited primarily by the Colorado River over the last 10 million years. The thickness of these sediments is about 20,000 feet. The reservoir is overlain by lake sediments which were deposited in the last few thousand years. These most recent deposits are in part the sealing caprock for the Salton Sea reservoir.

Recent faulting and volcanic activity near the Salton Sea created the geothermal resource. The reservoir sand, silts and clays show increasing consolidation and alteration with depth. This is due to interaction with increasing temperatures and reservoir fluid salinity with depth. The typical reservoir fluid exceeds 450°F (230°C) and is seven times more salty than sea water. The challenge in developing the Salton Sea reservoir has been learning how to handle these hot, highly saline brines.

THE STEAM GATHERING SYSTEM

Two producing wells are centrally located within the Salton Sea project area. These wells produce a total of 4,300,000 pounds per hour (lbs/hr) of hot fluid to the resource production facility. Flowing wellhead pressures range from 400 to 475 psig. Steam is processed here, then delivered to the dual inlet turbine at the electrical generating plant. Figure 2 (page 12) is a schematic of resource production and power generation. Figure 3 (page 13) shows the well and facility layout.

The fluid from each producing well flows to large, high pressure wellhead separators where the two-phase mixture of steam and liquid brine is separated. The steam exits the top of each separator through a pressure controller and enters the main steam line to the power plant. The concentration of carbon dioxide and other noncondensible gases in the flashed steam is low enough to permit the steam to go directly to the power plant without imposing an excessive load on the vacuum producing equipment of the condenser.

The liquid brine exits each wellhead separator and is combined into a single stream which is directed into the standard pressure crystallizer. The steam is flashed at slightly above delivery pressure of 100 psig. This steam, along with that flashed from the wellhead separator, is cleaned in two scrubber vessels. Most of the remaining particulates and moisture are removed in the scrubbers.

The brine flows from the bottom of the standard pressure crystallizer to a low pressure crystallizer where pressure is further reduced. The steam leaves the top of this separating vessel and is directed into the low pressure steam line leading to the turbine. This steam is also cleaned in two scrubbing vessels prior to entering the turbine. The remaining brine from the low pressure crystallizer flows to an atmospheric separator for final steam/brine separation.

As steam is flashed in the above processes, the brine cools and the concentration of dissolved material increases. In this supersaturated condition, various compounds tend to come out of solution and form solid particles suspended in the brine. In the crystallizers, these particles tend to grow to a size which can be readily separated from the brine. This particle growth process also inhibits the very small particles from adhering to the vessel walls and downstream piping.

Maintaining balanced brine flow and stabilized vessel conditions was initially forecast as difficult. For this reason, there are two parallel trains of high and low pressure crystallizers and atmospheric separators. Each train is capable of handling up to 80% of the plant flow. One train can be serviced without interrupting plant operations.

The brine flows from the atmospheric separator into the clarifier. Here the suspended particles grow even larger and settle to the bottom of the vessel where they are removed. The clean brine rises to the top of the clarifier and flows to the secondary clarifier for final cleaning. The treated brine is then pumped through pipelines to the field injection wells.

The solids collected from the clarifiers are dewatered in a filter system. The solids are beneficially used in a construction grade soil cement which is placed in the field. The crystallizers, clarifiers and dewatering filter are similar to equipment of the kind which might be found in a heavy chemical, ore processing or waste treatment plant, with special modifications for the unique geothermal environment.

The three brine injection wells are located at the south end of the field. Together, they dispose of a total of 3,200,000± lb/hr of clarified brine.

If, for any reason, the power plant turbine must be shut down, the steam is automatically discharged to the atmosphere through a rock muffler until turbine operations are resumed, or the resource production facility is shut down. The brine can be directed to a brine storage pond in case of a malfunction in the production or injection equipment. The pond can maintain full load operation for three hours.

THE SALTON SEA POWER PLANT

The Unit 3 power plant, owned by Desert Power Company, is located adjacent to the Unocal resource production facility (see Figure 3, page 13).

The design steam flow rates to the power plant are 623,000 lbs/hr of standard pressure steam at 100 psig, and 262,000 lbs/hr of low pressure steam at 10 psig. These two steam trains flow to the turbine. The turbine is a 54,000-kilowatt, 3600 rpm, dual flow, dual pressure unit with five stages. The first two stages are impulse type and the last three are reaction type blades. The last stage blades are 25 inches long. Steam from the turbine is exhausted to the main condenser which is a dual pressure design.

Corrosion resistant stainless steels were used extensively in the construction of the surface condenser. All condensate from the plant is used for cooling tower makeup or returned for injection. Noncondensible gases are removed from the main condenser by three stages of steam-jet ejectors. The ejectors require a total of 40,000 lbs/hr of steam at 90 psig to remove 6,500 lbs/hr (design) of air and other noncondensibles from the main condenser. Noncondensible gases and motive steam from the ejectors flow to shell and tube type condensers, the last stage of which operates at a pressure of 0.9 psig. Steam condensate from the air ejector-condenser drains into the main condenser, from which it is returned to the resource production facility.

The noncondensible gases from the power plant are mixed with the air stream being discharged by the fans on the cooling tower. The seven cell, induced draft cooling tower is designed to cool 82,000 gpm of water from 100°F to 80°F, for a heat load of 820 MMBtu/hour. Makeup water to the tower is provided from stored condensate.

The Unit 3 power plant is designed to deliver 47,500 kilowatts to the Southern California Edison Company in the Coachella Valley. The amount of energy generated is sufficient to meet the needs of an estimated 50,000 residential customers, and can save about 500,000 barrels of oil per year.

OPERATIONS

Brine first flowed to the resource production facility on December 14, 1988. After successful testing of the brine-handling and power generation systems, the power generating plant achieved commercial operation on February 14, 1989. The plant has run continuously since that time at more than 95 percent capacity.

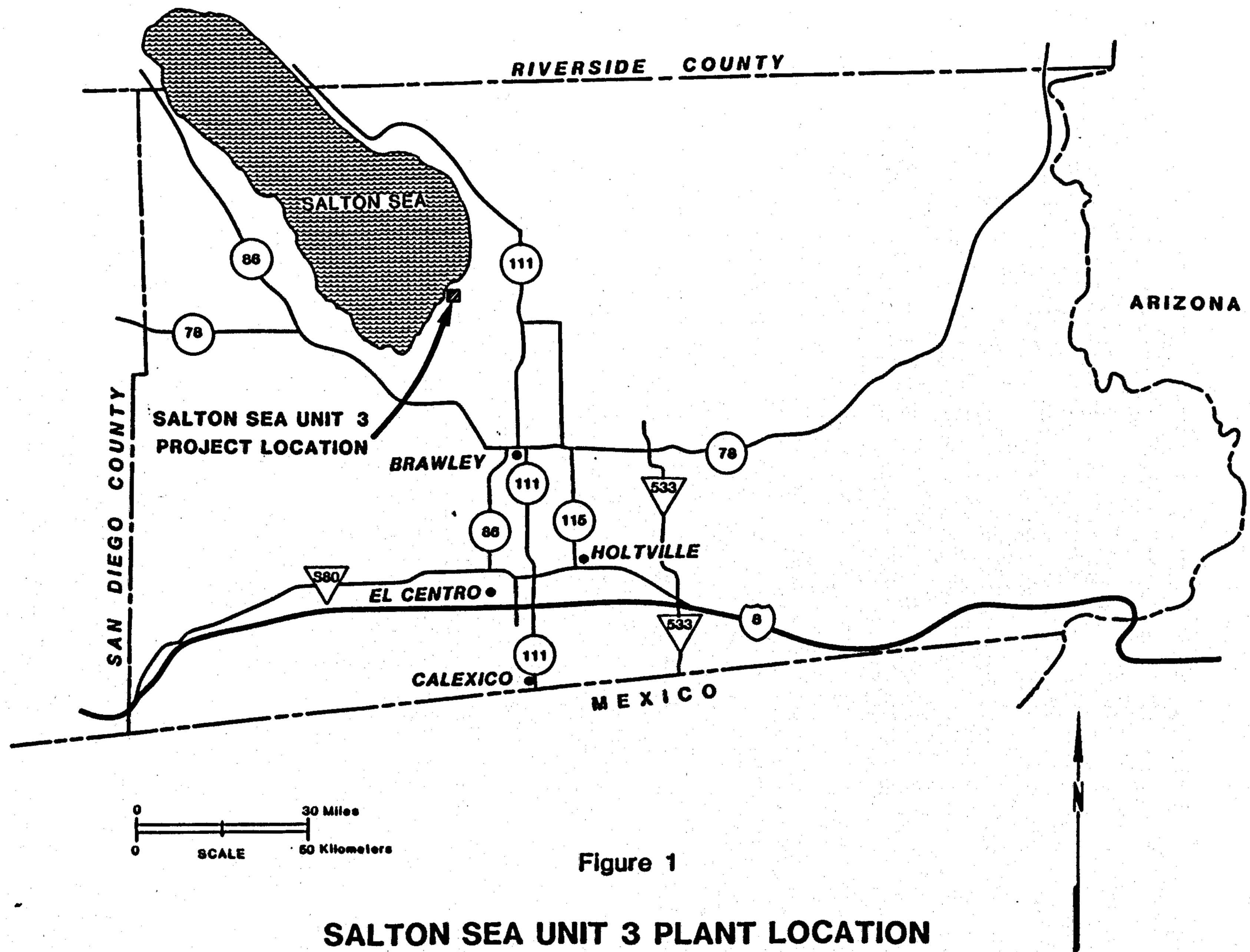

Figure 1

SALTON SEA UNIT 3 PLANT LOCATION

IMPERIAL VALLEY, CALIFORNIA

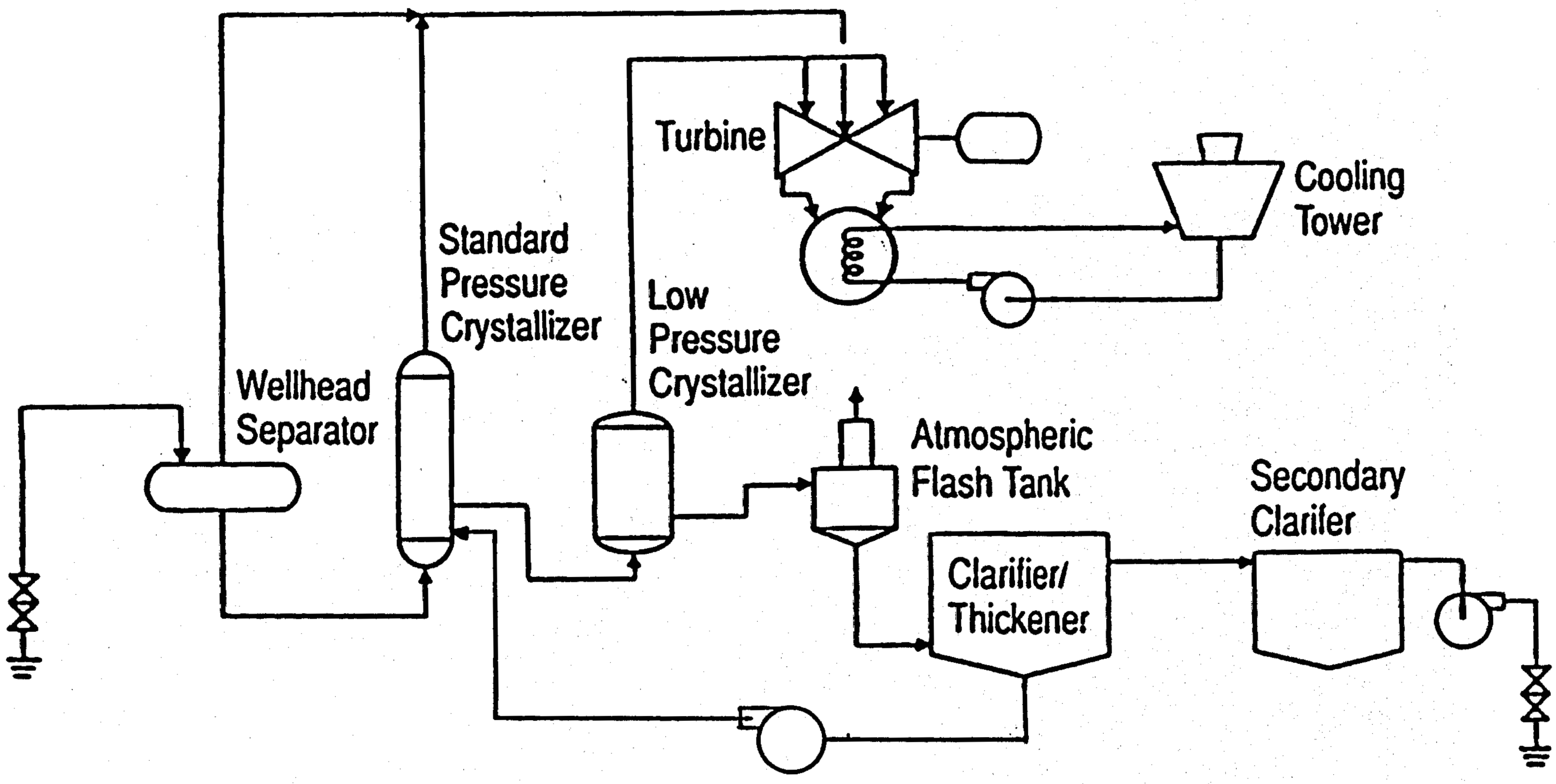

Figure 2

SALTON SEA UNIT 3
SIMPLIFIED PROCESS SCHEMATIC

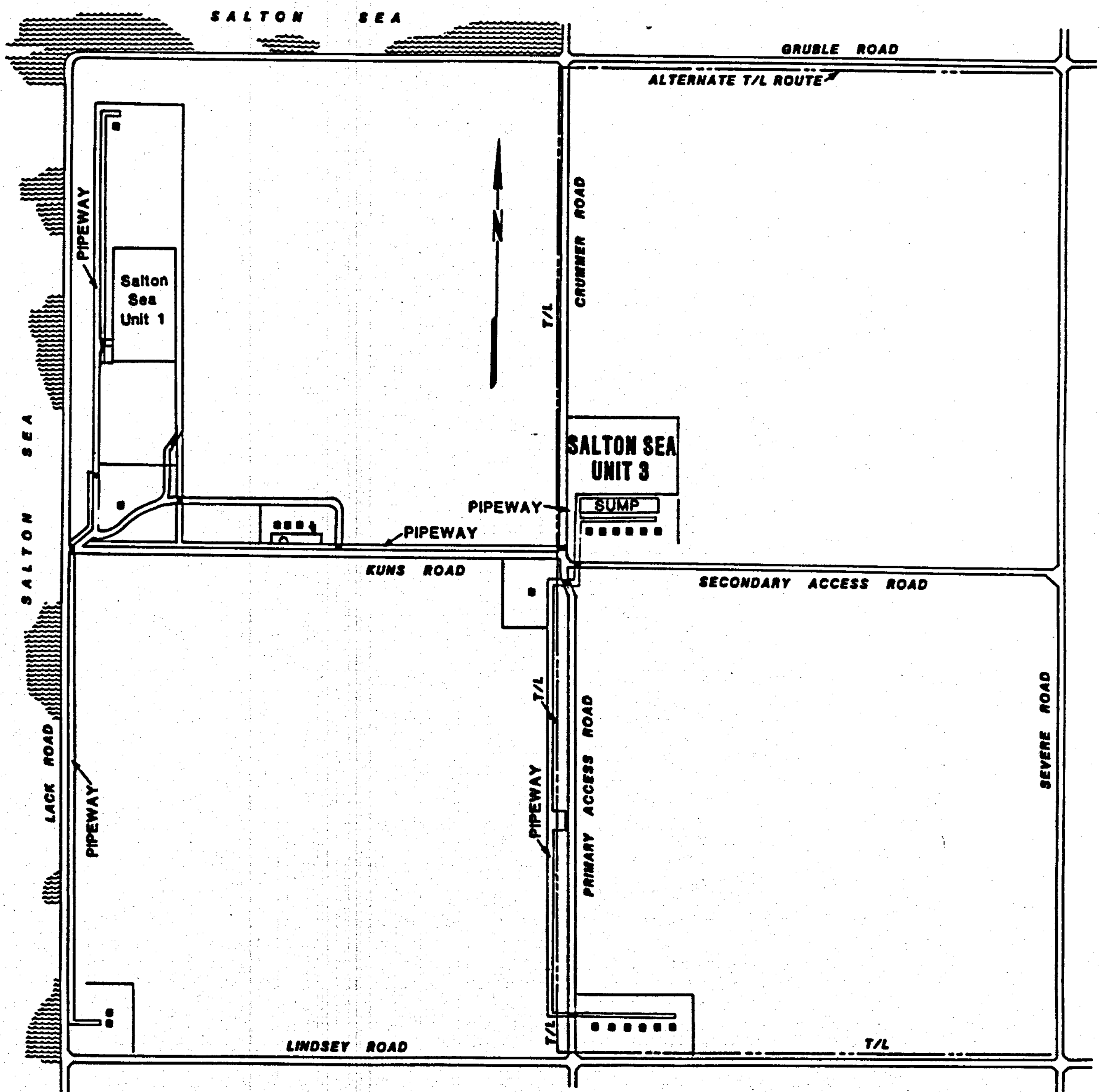

Figure 3

SALTON SEA UNIT 3
WELL AND FACILITY LAYOUT

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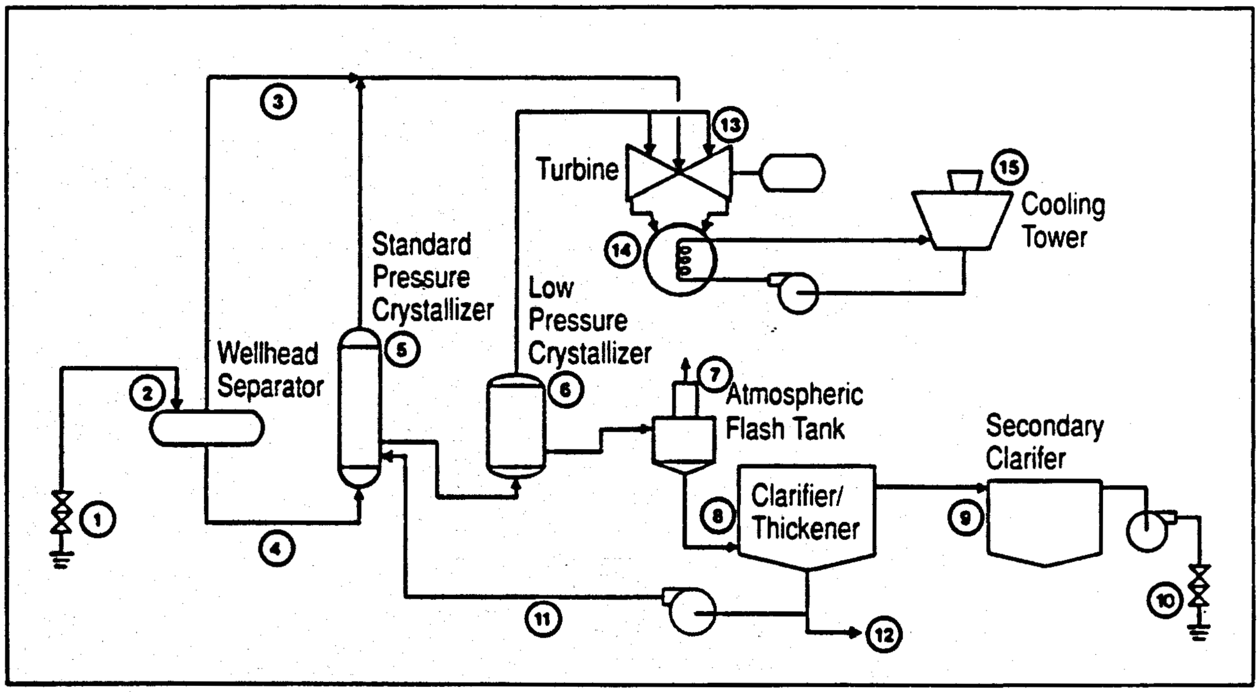
SALTON SEA UNIT 3
SIMPLIFIED PROCESS SCHEMATIC



Geothermal brine flows naturally from a production well (1) into a wellhead separator (2). There, high pressure steam (3) is separated from the liquid brine and directed to the steam turbine.

Brine flows (4) from the wellhead separator into the standard pressure crystallizer (5). Reduced pressure causes additional steam to flash. The steam leaves the top of the vessel and flows to the steam turbine along with the high pressure steam.

Brine flows from the standard pressure crystallizer into the low pressure crystallizer (6), where further pressure reduction produces more steam. This steam flows to the turbine through a separate pipeline.

The brine is then reduced to atmospheric pressure (7) and flows by gravity into a clarifier/thickener (8) and a secondary clarifier (9). Both vessels remove solids that have precipitated from the brine. The remaining fluid is clean enough to be injected into the reservoir without plugging the injection wells (10).

Solids are recycled (11) to the crystallizers as seed material, minimizing the formation of scale in the vessels and pipes. Excess solids produced in the process are removed (12) and used as a building material on site.

Steam turns the turbine-generator (13). Spent steam is exhausted into a shell and tube condenser (14), which recovers the steam as water. The condenser is cooled by water from the cooling tower (15).